Name: Sunny-Ade Ubomazekie-Oniso Fortress

Department: Mechatronics Engineering

Matric No.:19/ENG05/061

Date:20/04/2020

Course code:PHY102

Name: Sunny-Ade Ubomazekie-Oniso Fortress
Department: Mechatronics Engineering
Date: 20/04/2020
Matric No: 19/ENG05/061
Course Code: PHY102 (Electricity and Magnetism)

Section A

1a) Explain with the aid of diagram, how you can produce a negatively charged spere by method of induction.

To produce a negatively charged spere by induction consider a positively charged rubber rod brought near a neutral uncharged conducting Sphere that is insulated so that there is no conducting path to the ground as shown in the diagram below.

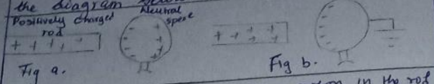


Fig a. Fig b.

The repulsive force between the proton in the rod and those in the spere causes a redistribution of charges on the sphere, so that some protons move to the side of the sphere farthest away from the rod (Fig a). The region of the sphere nearest the positively charged rod has an excess of negative charge because of the migration of protons away from the location. If a grounded conducting wire is then conducted to the sphere as in (Fig b), some of the protons leave the spere and travel to the earth and if the wire is removed (Fig c) the conducting spere is left with excess of induced negative charges. Finally when the rubber is removed from the vicinity of the sphere (Fig d) the induced negative charge remains on the ungrounded spere then becomes evenly distributed around the spere.

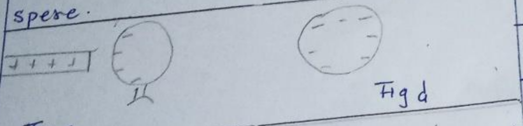


Fig c Fig d

b) Each of two small speres is charged positively the combined charge being $5.0\times10^{-5}C$. If each sphere is repelled from each other by a force of 1N when the spheres are 2.0m apart, calculate the charge on each sphere.

Solution

Combined Charge $q_1+q_2 = 5.0\times10^{-5}$ C, $F = 1N$

$r = 2.0m$, $K = 9\times10^9 Nm^2/C$

From Columbs law $F = \frac{kq_1 q_2}{r^2}$

Let the product of the charges $q(p)$

$q(p) = \frac{(1\times 2)^2}{9\times10^9} = 4.44\times10^{-10}C^2$

$q_1+q_2 = 5.0\times10^{-5}C$ (1) $q_1q_2 = 4.44\times10^{-10}C$ (2)

Substitute $q_1 = 5.0\times10^{-5} - q_2$ in — (2)

$= (5.0\times10^{-5} - q_2)\times q_2 = 4.44\times10^{-10}$

$= q^2 + (5.0\times10^{-5})q_2 - 4.44\times10^{-10} = 0$

Using formular method

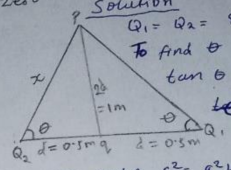
$q_2 = \frac{(5.0\times10^{-5}) \pm \sqrt{(5\times10^{-5})^2 - 4\times(-4.44\times10^{-10})}}{2}$

$q_2 = 3.84\times10^{-5}$

$q_1 = 5.0\times10^{-5} - 3.84\times10^{-5} = 1.16\times10^{-5}$

c) Three charges were positioned as shown in the figure below. If $Q_1 = Q_2 = 8uc$ and $d = 0.5m$, determine q if the electric field at P is zero.

Solution



$Q_1 = Q_2 = 8uC$

To find θ use $\tan\theta = \frac{opp}{ady}$

$\tan\theta = \frac{1}{0.5} = 2, \theta = \tan^{-1} 2$

$= 63.45°$

To find x use Pythogoras rule $c^2 = a^2 + b^2 \therefore x^2 = 1^2 + 0.5^2$

$\therefore x = \sqrt{1^2+0.5^2} = 1.12m$

$E_1 = \frac{Kq_1}{r^2} = \frac{9\times10^9\times8\times10^{-6}}{1.12^2} = 5739.795918$

Since $q_1 = q_2 \therefore E_2 = 5739.79518$

$E_3 = \frac{9\times10^9\times q}{1^2} = 9\times10^9 q$

vector	θ	x-component	y-component
E_1	63.4	5739.795918 cos 63.4 = 25673.15	5739.795918 Sin 63.4 = 51336.08
E_2	63.4	−5739.795918 cos 63.4 = −25673.15	5739.795918 Sin 63.4 = 51336.08
E_3	90°	= 0	= $9\times10^9 q$
		$\Sigma x = 0$	$\Sigma y = 102672.16$

Magnitude $= \sqrt{\Sigma x^2 + \Sigma y^2}$

$E_q = \sqrt{0^2 + (102672.16)^2} = 102672.16$

Since $\Sigma x = 0$

$102672.16 - 9\times10^9 q = 0$

$q = \frac{-102672.16}{9\times10^9} = -11.4uC$

2) a) Distinguish between the terms: Electric field and electric field intensity.

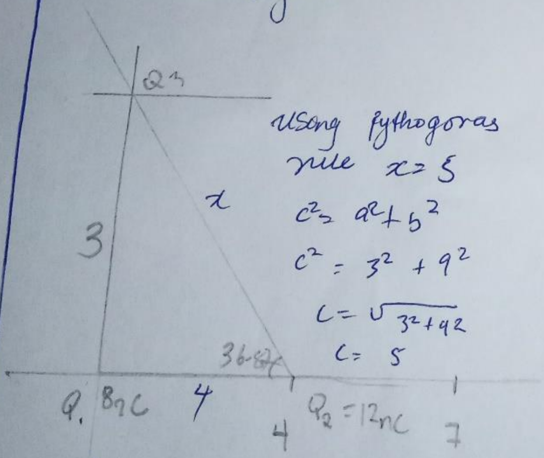
<u>Answer</u>

Electric field is a region of space in which electric charges will experience an electric force. While Electric intensity is the force per unit charge.

b) A positive charge $Q_1 = 8nC$ is at the origin, and a second positive charge $Q_2 = 12nC$ is on the x-axis at $x = 4m$. Find

i) The net electric field at a point P on the x-axis at $x = 7m$

ii) the electric field at point Q on the y axis at $y = 3m$ due to charges.



Using pythogoras rule $x = 5$

$c^2 = a^2 + b^2$

$c^2 = 3^2 + 4^2$

$c = \sqrt{3^2 + 4^2}$

$c = 5$

<u>Solution</u>

$E_1 = \frac{KQ}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{7^2}$

$= 1.469$

$E_2 = \frac{KQ_2}{} = 9 \times 10^9 \times 12 \times 10^{-9}$

The net electric field $= 13.469 \approx \underline{\underline{13.5}}$

ii) $E_1 = \frac{KQ_1}{r^2} = \frac{9 \times 10^9 \times 8 \times 10^{-9}}{3^2} = 8N/C$

$E_2 = \frac{KQ_2}{r^2} = \frac{9 \times 10^9 \times 12 \times 10^{-9}}{5^2} = 4.32N/C$

$\tan\theta = \frac{opp}{adj} = 3/4$

$\tan^{-1} 3/4 = \underline{\underline{36.87°}}$

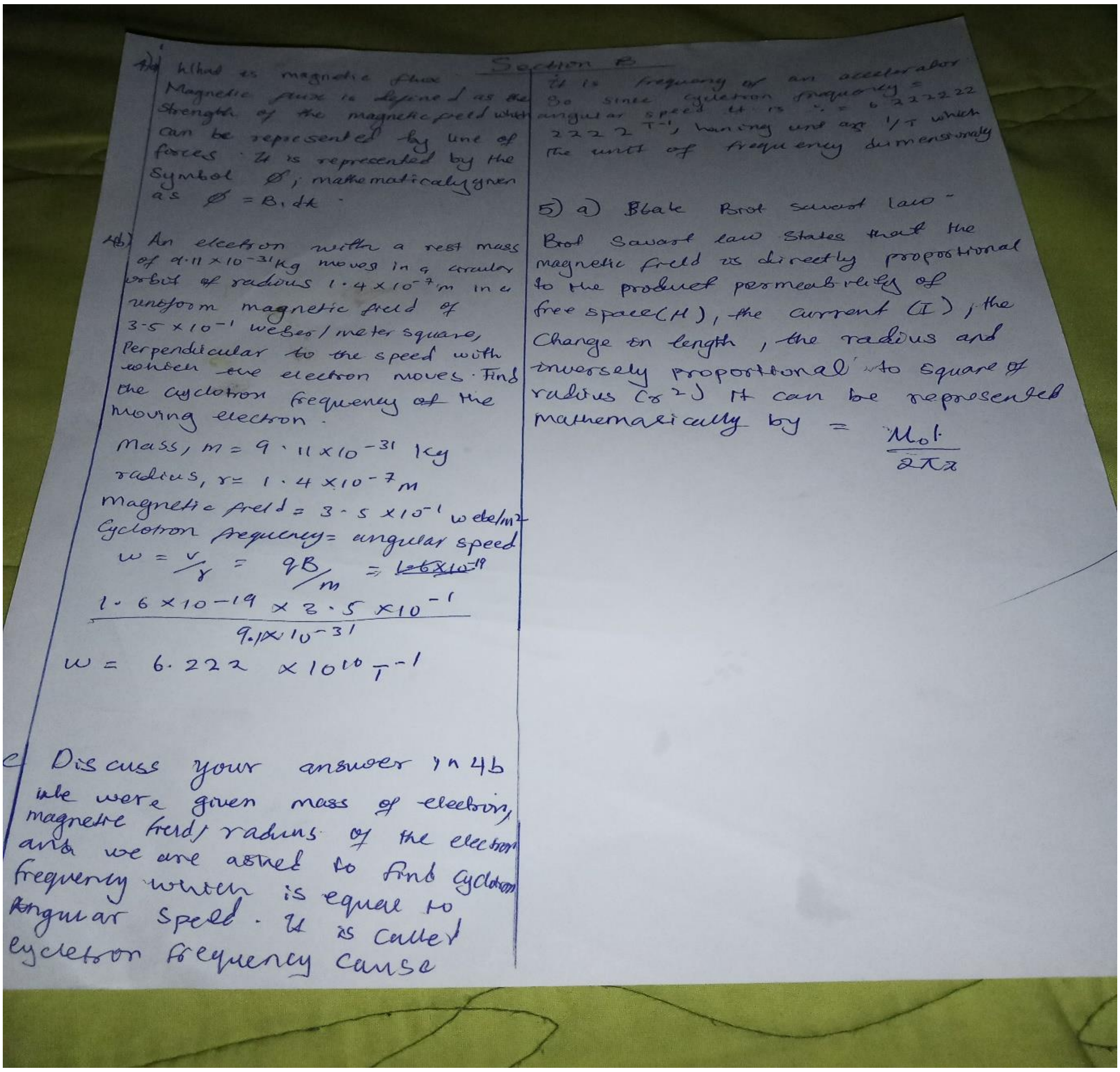
Vector	θ	x component	y component
$E_1 = 8 N/C$	90°	$8 \cos 90 = 0$	$8 \sin 90 = 8$
$E_2 = 4.32 N/C$	36.87	$4.32 \cos 36.87 = -3.4554$	$= 4.32 \sin 36.87 = 2.5920$
		$\Sigma x = -5.4559$	$\Sigma y = 10.5920$

$E_{net} = \sqrt{\Sigma fx^2 + \Sigma fy^2}$

$= \sqrt{(-3.4559)^2 + (10.5920)^2}$

$= \sqrt{124.08}$

$= 11.14 N/C$



4a) What is magnetic flux
Magnetic flux is defined as the strength of the magnetic field which can be represented by line of forces. It is represented by the symbol Ø; mathematically given as Ø = B.dA.

4b) An electron with a rest mass of 9.11×10⁻³¹kg moves in a circular orbit of radius 1.4×10⁻⁷m in a uniform magnetic field of 3.5×10⁻¹ weber/meter square, perpendicular to the speed with which the electron moves. Find the cyclotron frequency of the moving electron.

Mass, m = 9.11×10⁻³¹ kg
radius, r = 1.4×10⁻⁷ m
magnetic field = 3.5×10⁻¹ weber/m²
Cyclotron frequency = angular speed

$\omega = \frac{v}{r} = \frac{qB}{m} = \frac{1.6\times10^{-19} \times 3.5\times10^{-1}}{9.11\times10^{-31}}$

$\omega = 6.222 \times 10^{10}\ T^{-1}$

c) Discuss your answer in 4b
We were given mass of electron, magnetic field, radius of the electron and we are asked to find cyclotron frequency which is equal to angular speed. It is called cyclotron frequency cause

Section B

it is frequency of an accelerator. So since cyclotron frequency = angular speed it is ∴ = 6.2222222222 T^{-1}, having unit as 1/T which the unit of frequency dimensionally

5) a) State Biot Savart law

Biot Savart law states that the magnetic field is directly proportional to the product permeability of free space (μ), the current (I), the change in length, the radius and inversely proportional to square of radius (r²). It can be represented mathematically by = $\frac{\mu_0 I}{2\pi r}$

Magnetic Field of a Straight Current Carrying Conductor

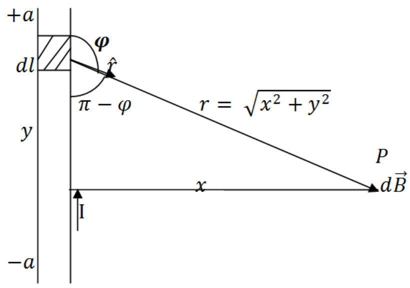


Fig 1: A section of a Straight Current Carrying Conductor

Applying the Biot-Savart law, we find the magnitude of the field $d\vec{B}$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a}\frac{dl \sin\varphi}{r^2}$$

$$sin(\pi - \varphi) = \ sin\theta$$

$$\therefore B = \frac{\mu_o I}{4\pi}\int_{-a}^{a}\frac{dl sin(\pi - \varphi)}{r^2}$$

From diagram, $r^2 = x^2 + y^2$ $(Pythagoras\ theorem)$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a}\frac{dl sin(\pi - \varphi)}{x^2 + y^2} \quad \ldots \quad (*)$$

$$But\ \ sin(\pi - \varphi) = \frac{x}{\sqrt{x^2 + y^2}} = \frac{x}{(x^2 + y^2)^{1/2}} \quad \ldots \quad (**)$$

Substituting $(**)$ into $(*)$, we have

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} dl \frac{x}{(x^2 + y^2)(x^2 + y^2)^{1/2}}$$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} dl \frac{x}{(x^2 + y^2)^{3/2}}$$

Recall $dl = dy$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} \frac{x}{(x^2 + y^2)^{3/2}} dy$$

$$B = \frac{\mu_o I x}{4\pi}\int_{-a}^{a} \frac{1}{(x^2 + y^2)^{3/2}} dy \quad \ldots \quad (***)$$

Using special integrals:

$$\int \frac{dy}{(x^2 + y^2)^{3/2}} = \frac{1}{x^2}\frac{y}{(x^2 + y^2)^{1/2}}$$

Equation $(***)$ therefore becomes

$$B = \frac{\mu_o I x}{4\pi}\left[\frac{y}{x^2(x^2 + y^2)^{1/2}}\right]_{-a}^{a}$$

$$B = \frac{\mu_o I x}{4\pi}\left(\frac{2a}{x^2(x^2 + a^2)^{1/2}}\right)$$

$$B = \frac{\mu_o I}{4\pi x}\left(\frac{2a}{(x^2 + a^2)^{1/2}}\right)$$

When the length $2a$ of the conductor is very great in comparison to its distance x from point P, we consider it infinitely long. That is, when a is much largerthan x,

$$(x^2 + a^2)^{1/2} \cong a, as\ a \to \infty$$

$$\therefore B = \frac{\mu_o I}{2\pi x}$$